

VALIDITY OF AXIS TRANSFER TECHNIQUE FOR PITCH DAMPING MEASUREMENTS

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Abstract

Results of some experimental investigations undertaken to verify the validity of axis transfer technique for transonic pitch damping measurements on high fineness ratio configurations are presented. Free oscillation tests on three half-models of fineness ratios 10 and 25 were conducted at Mach numbers between 0.7 and 1.2, with three different axes of oscillation. The measured pitch-damping derivatives for two axes were used to compute the derivative for the third axis. Comparison between the transferred and the measured derivatives was, in general, good for Mach numbers between 0.7 and 1.0 and poor for Mach numbers 1.1 and 1.2.

I. Introduction

Measurement of aerodynamic damping derivatives are usually obtained for a reference center at or near the center of gravity of the configuration. But situations which necessitate evaluation of damping derivatives for a new reference center using known data at other reference centers occur frequently. For example, mechanical interference between the model and sting may not permit model oscillations of sufficient amplitude about the c.g. location. This problem which is common for long slender models particularly in pressurized tunnels where strength and stiffness considerations govern the minimum sting and maximum model sizes, is overcome by conducting tests for aft centers of oscillation and the required derivatives about c.g. locations are obtained by a transfer of the measured data. A reliable transfer technique would provide damping data for all desired locations from the measurements about two convenient oscillation centers only, resulting in considerable reduction of testing requirements.

Derivative transfer can be accomplished by the well known transfer equations which are derived by linearly superposing the effects of different perturbation velocities (See Ref. 1 for details). From these equations it can be shown that the pitch-damping derivative for any reference center can be computed from the damping derivatives and the normal force slope data at two other reference centers. This technique was applied for blunt re-entry

type bodies and a poor agreement between the transferred and the measured pitch-damping derivatives was observed by Wehrend and Reese². Later investigations³ on a 12° semi-vertex angle cone with sharp and blunt tips showed a favorable comparison between the transferred and the measured data. From similar tests on a Basic Finner model at subsonic speeds, Nicolaides and Eikenberry⁴ concluded that the transfer equations were satisfactory. But Meyer and Seredinsky⁵ point out that the usual transfer equations are invalid at moderate to large angles of attack and when large distances are involved and propose new transfer equations applicable at large angles of attack. But a general validation of the transfer technique for different parameters such as configuration variations, Mach number, transfer distance etc. and in particular for slender configurations at high speeds (for which the need is maximum as discussed earlier) does not seem to have been established.

This paper describes the results of some experimental investigations undertaken to verify the validity of transfer technique for pitch-damping derivatives of three slender configurations at transonic speeds. Some results for Mach numbers of 2.0 and 2.48 are also included.

II. Transfer Equation

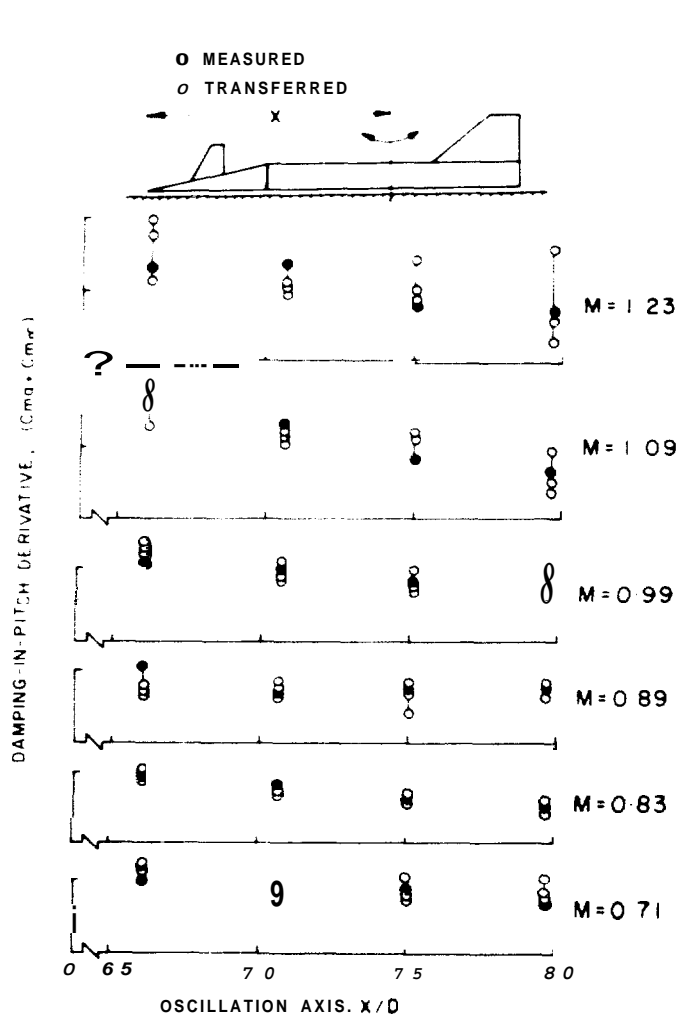
Equations for transfer of aerodynamic derivatives referred to a given axis system to any other arbitrarily oriented axis system are derived in Ref. 1. For the simple and more common case of only longitudinal separation of axes, the following equation for the unknown damping-in-pitch derivative in terms of the known derivatives about two other axes (or reference centers) and the normal force slope of the configuration can be derived as:

$$(C_m + C_{m\alpha})_0 = \frac{x_{01}(C_m + C_{m\alpha})_2 - x_{02}(C_m + C_{m\alpha})_1}{x_{01} - x_{02}} - \frac{x_{01} \times x_{02}}{l_1 l_2} C_{N\alpha}$$

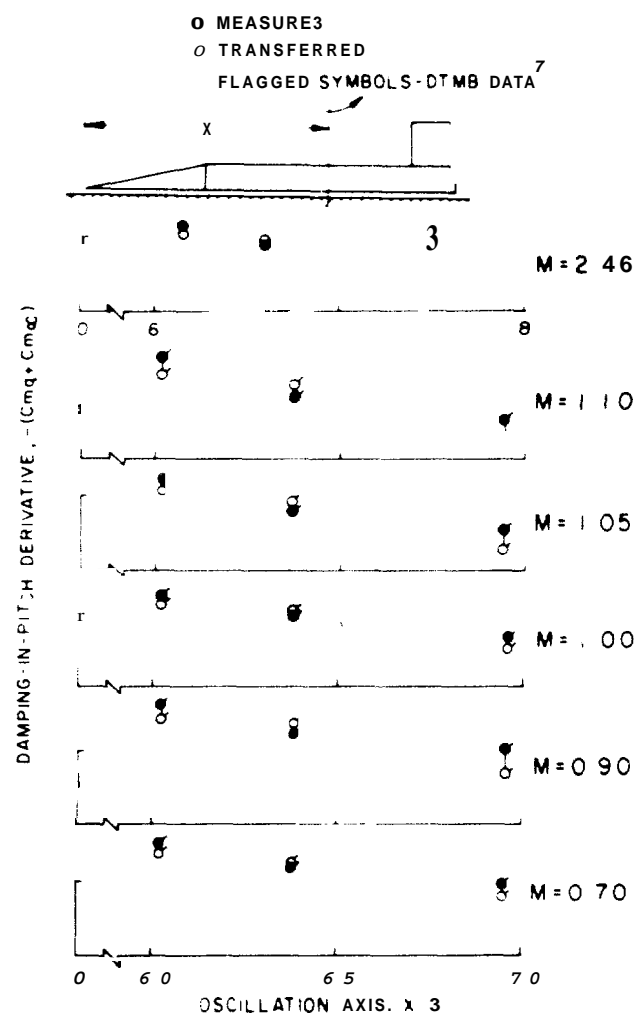
where the subscripts refer to the axes indicated and the distances x_{01} and x_{02} are as indicated in Fig. 1. l_1 and l_2 are reference lengths,

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(b) Model 2



(c) model 3

Fig. 3 (concluded)

Agreement between the two data was generally poor at Mach numbers of 1.09 and 1.23 for models 1 and 2, while it was not so bad for model 3 at $M = 1.05$ and 1.1. With the limited data available it is not possible to explain the above disagreement. It is likely that due to the presence and movement of shocks on the body at transonic speeds the transfer technique, which derives the effects of pitching about an axis by superposing the separate effects of pitching and plunging about another axis (as illustrated in Ref. 3) may have some limitations.

Damping measurements were made for four different oscillation axes for model 2 and hence it was possible to compute, for each axis, three different transferred derivatives by considering any two of the other three axes. It thus enabled a study of the effect of relative locations of the axes on the transfer technique. Agreement between the transferred and the measured derivatives was, in general, found to be better when the distance

between the axes about which the measurements were obtained was larger.

V. Conclusions

On the basis of the present investigations, the axis transfer technique is, in general, found to be valid for slender configurations at transonic speeds. However, the technique is of doubtful validity in certain critical cases presumably due to the presence and movement of shocks on the body at transonic speeds. This and other limitations of the transfer technique need to be identified by more extensive investigations.

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